Workshop Time: Approximately 2-3 hrs.

Equipment Requirement: Use Writing Boards (any type) to document students' responses to Case Study HFACS-ME analysis, risk assessments, and intervention strategies.

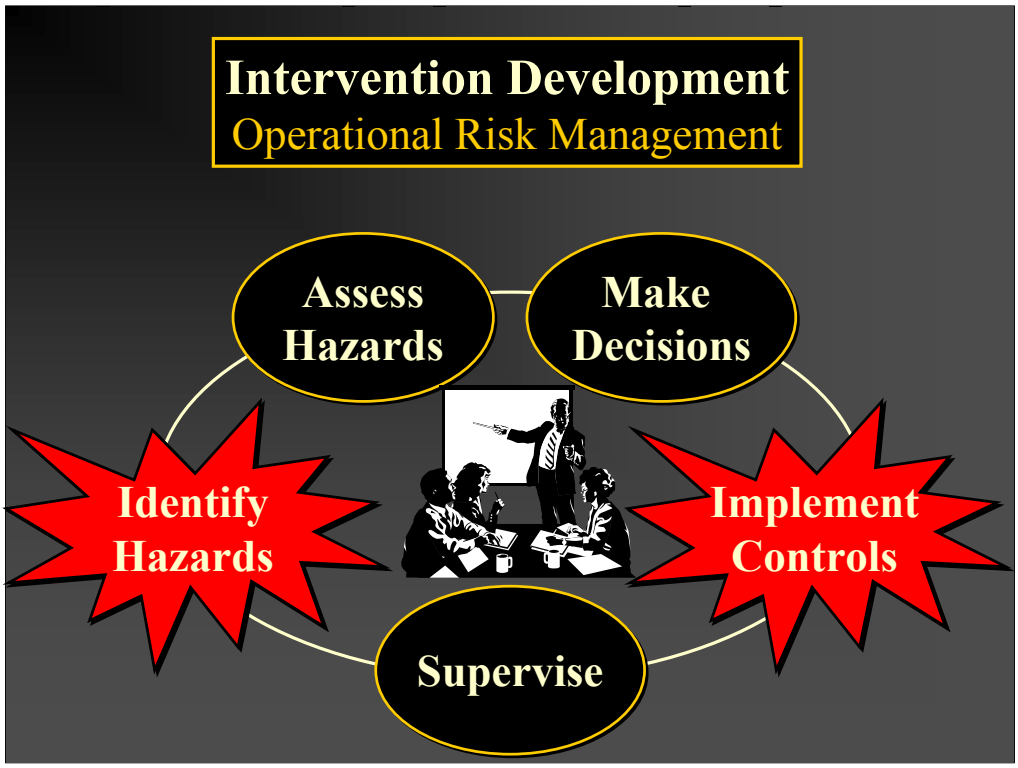
Facilitator: Ensure students have copies of all Case Studies that are available in the Student Guide.

Welcome to this workshop on Aviation Maintenance Human Factors Interventions.

The purpose of this group-oriented, Case Study Training is to provide managers, supervisors, investigators, and other safety personnel with the opportunity to apply the principles learned from the previous Human Factors presentations.

The previous presentations have provided extensive information on human factors, accident investigations, risk assessment and intervention strategy development.

It is now time to see what you have learned… (quickly go to next slide)



We will analyze two Case Study Accidents during this workshop.

In accordance with this basic Operational Risk Management model, we will:

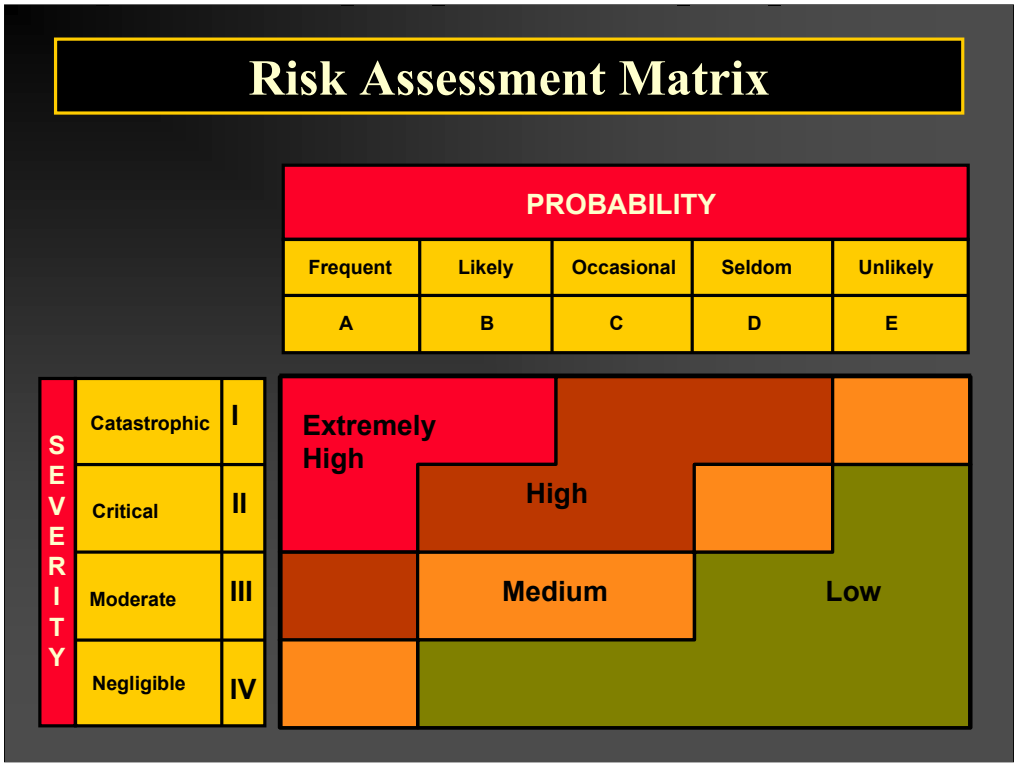
1. **Identify the Hazards**
2. **Assess the Hazards**, and
3. **Make Decisions** on Intervention Strategies

Implementing and **Supervising** those decisions will also improve as a result of this training.

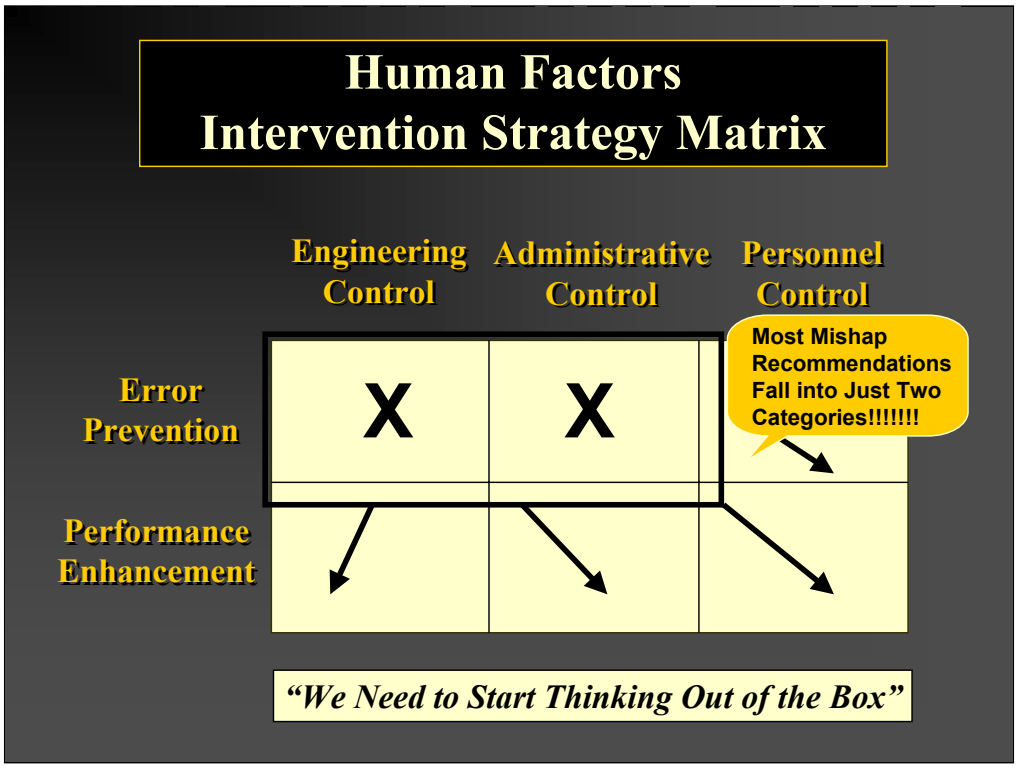
HFACS-ME Framework

Error Categories of HFACS Framework				
First Order	**Second Order**	**Third Order**		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

1. To **Identify the Hazards**, we will refer back to our HFACS-ME taxonomy to analyze and categorize accident causal factors.



2. To **Assess the Hazards** (Cause Factors), we will classify their Risk Potential within the Risk Assessment Matrix.



3. And to **Make Decisions** on recommended corrective actions, we will utilize our Human Factors Intervention Strategy Matrix to "think outside the box".

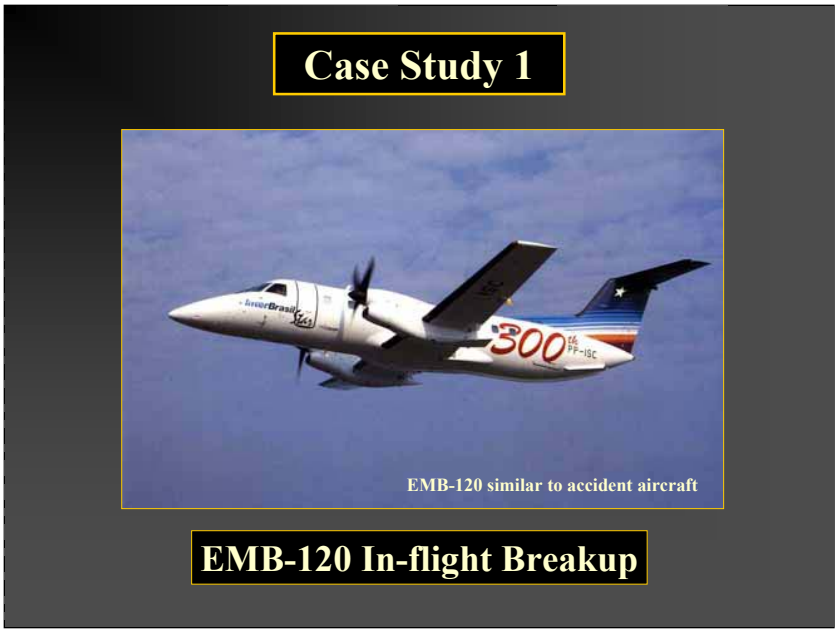


Photo: EMB-120 from Embraer Website at http://www.embraer.com/ing/av120c.htm

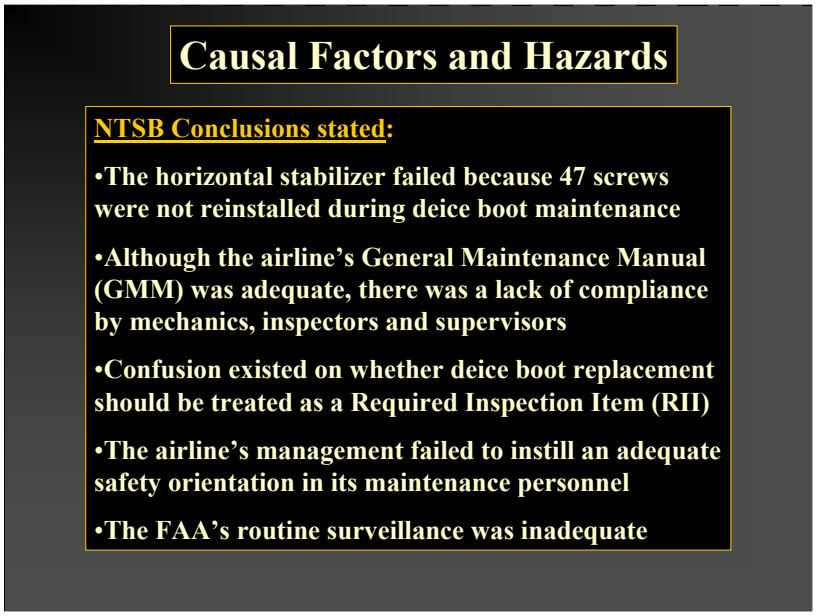
Our first case study involves routine maintenance.

Although the NTSB report is 87 pages long, the synopsis that you have been provided incorporates the main factors involved in this accident. You will notice that a "simple", yet tragic accident, is often caused by a series of system errors, vice a horrible error on the part of any single individual.

Please carefully read CASE STUDY #1 at this time. After you finish reading, we will discuss your observations, the NTSB's conclusions, and apply our findings to the HFACS-ME framework (utilizing the HFACS-ME templates in the Student Guide). You will see that the NTSB findings can easily be classified within the HFACS-ME framework categories. You will also find that we will identify additional HFACS-ME factors, not as obvious from the NTSB's probable and contributing causes statements, that will also be crucial for successful prevention of similar accidents.

You are encouraged to take notes and you may refer to the HFACS-ME framework at any time during this workshop.

(Facilitator: Allow no more than 10-15 minutes to read the case study. The follow-on group discussion will clarify any issues missed by the slower readers.)



Facilitator: Allow the students time to state the factors and hazards that they found before advancing to the slide's bullets. Facilitators are encouraged to use a separate board or paper to list the students' findings.

What are some causal factors and hazards involved in the course of this accident?

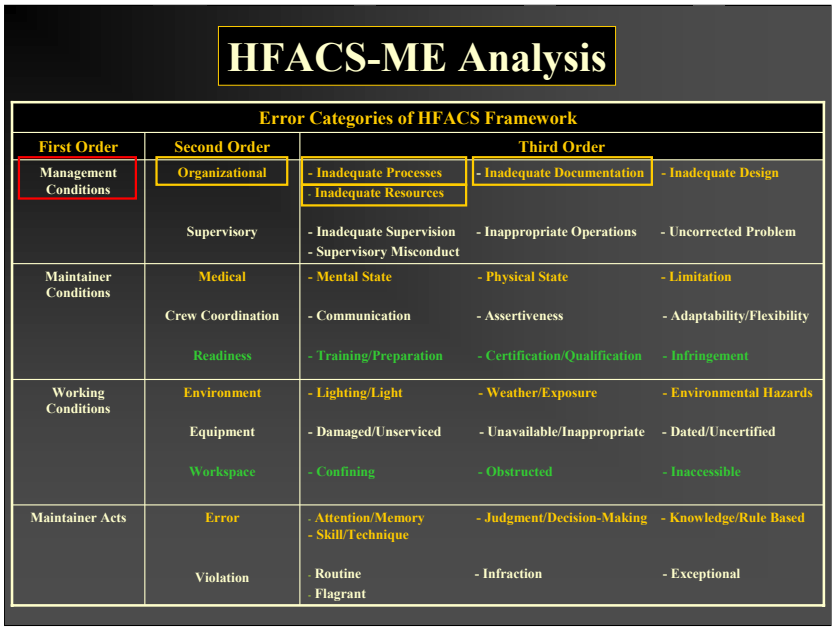
As you see in the Case Study in front of you, the NTSB cited 19 conclusions. The first nine describe the breakup and non-factor conclusions. The remainder can be summarized by (advance slide to show bullets):

- The horizontal stabilizer failed because 47 screws were not reinstalled during deice boot maintenance
- Although the airline's General Maintenance Manual (GMM) was adequate, there was a lack of compliance by mechanics, inspectors and supervisors
- Confusion existed on whether deice boot replacement should be treated as a Required Inspection Item (RII)
- The airline's management failed to instill an adequate safety orientation in its maintenance personnel
- The FAA's routine surveillance was inadequate

A future accident depends upon correcting the deficiencies, errors, and hazards involved in this accident. Does this list include all of the accident details that you found in the Case Study? No. This case study actually provides some additional factors that we can consider, and it probably raises some questions in your mind about other non-causal problems that need to be further addressed.

In other words, most investigations uncover a majority of the factors, but several of those factors become "watered down", lost, or incorporated into a larger single cause factor "summary" such as this accident's Probable Cause Statement, "The failure of maintenance and inspection personnel to adhere to proper maintenance and QA procedures for the airplane's horizontal stabilizer deice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-down pitch over and breakup of the airplane."

So let us now refer to our HFACS-ME Framework to help us further identify and categorize some of the other factors that we just read about. **(quickly go to next slide)**



Facilitator: Time permitting, discuss student HFACS "choices" prior to advancing the slide to reveal the "boxed answers".

We must first consider our HFACS-ME findings…

Let's start with the **Management Conditions**. As you recall, the **Organizational** Categories involve factors emanating from upper Airline Management, the Manufacturer, and regulatory agencies.

Are there Management–Organizational-Third Order Categories in this accident?

Inadequate Processes - **Yes**. There is consistent evidence of improper maintenance practices, turnover violations, and documentation failures. There are also discipline and certification issues concerning the inspector who removed the screws and was previously warned. Upper management failed to track and correct these safety issues and failed to foster an overall safety culture. The FAA overburdened the sole PMI by not augmenting his manning, by requiring him to train his subordinates (and relief), and by relying too greatly on paperwork surveillance of maintenance practices.

Inadequate Documentation - **Yes**. There was ambiguity between the manufacturer, the FAA, and the airline on the specific identification of published Required Inspection Items (RIIs). The work card even had "yes" circled by the RII, but organizational procedures contradicted the card. Also, there is no documentation that requires notification of aircrews concerning critical maintenance repairs. (Note: the General Maintenance Manual, or GMM, was adequate but not followed. Failure to use a manual could fall under several other categories).

Inadequate Design No. There were no defects in the design of the aircraft or maintenance equipment.

Inadequate Resources -**Yes**. The maintainers were not provided with sufficient hangar space and/or outside lighting to adequately conduct the expected maintenance. And, although the evidence is not clear in the case study, the hydraulic lift may not be satisfactory for maintenance on top of the T-tail. (If this happened routinely and was either ignored or expected by upper management, you would have a strong case to also categorize this as Inadequate Processes. The current evidence suggests that it happens very rarely.) The FAA also provided insufficient personnel to conduct inspections on the growing airline. The NTSB dissenting statement further cited a lack of a Lead Mechanic and a Lead Inspector.

HFACS-ME Analysis

Error Categories of HFACS Framework				
First Order	**Second Order**	**Third Order**		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Are there Supervisory Third Order factors as well?

Inadequate Supervision -**Yes**. Supervisors and inspectors not only failed to monitor and enforce published procedures, they were some of the key violators. Improper documentation of maintenance actions, turnover failures, poor control of parts (screws) and frequent shifts in schedules and team composition were directly causal to this accident.

Inappropriate Operations -**Yes**. A conscious decision was made by the second shift supervisor to begin work on the deice boots without using the work cards. The aircraft was purposely moved outside, in the dark, so that additional maintenance could be conducted on another aircraft.

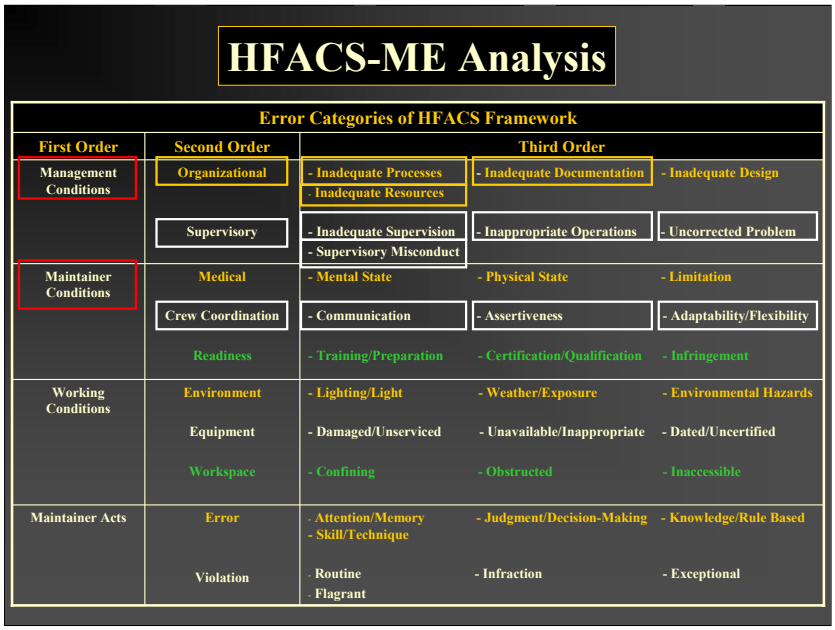
Uncorrected Problem -**Yes**. Routine turnover and documentation issues were allowed to continue without significant correction. Discipline and certification of the second shift inspector created a culture in which safety errors and violations were becoming the norm.

Supervisory Misconduct -**Yes**. The second shift supervisor directed that the boot replacement begin without the use of work cards. Inspectors conducted maintenance. Supervisors left work without conducting adequate turnovers.

Did this HFACS-ME classification of factors alter the evidence in the NTSB report or change the "probable/contributing causes"? No. However, it did clarify the factors involved. The NTSB probable and contributing causes only state "the failure of maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures" and the "failure of management to ensure compliance…." If you were management, what would your recommendation be based only upon those NTSB statements? "Fire or discipline everyone at the local level?" How about if you were part of the local personnel? "It's managements fault and they don't care anyway?"

HFACS demonstrates that upper management, local supervisors, and the entire organization have accountability towards both the accident cause factors and the subsequent corrective actions. It is time to stop pointing fingers at each other and direct safety interventions at their appropriate areas. HFACS defines those areas.

Let us now continue on to Maintainer Conditions (go to next slide).



How about Maintainer Conditions?

Are there any Medical issues?

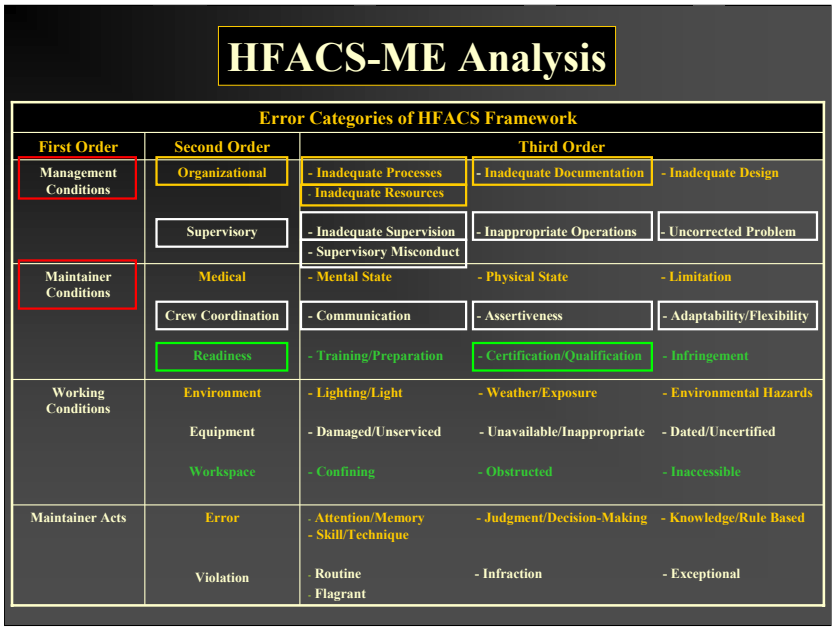
Possibly, but the NTSB said their were no drug/alcohol problems and no background or behavioral issues. There is also no evidence of any problems with limitations in physical size or strength. And finally, although maintenance was done during the evening and night shifts, there is no evidence in this case study to suggest fatigue. **However**, even though we are not appointing any medical category at this time, the HFACS-ME Framework still reminds investigators to thoroughly check into those factors, and if a medical Third Order factor is discovered, HFACS-ME can again categorize it within the other maintainer conditions. **HFACS-ME is therefore an effective tool for both investigations and analysis! Further investigation of factors within the Mental State category is strongly advised considering the possibilities of perceived pressure to finish the aircraft (they only did half the task and pushed it out of the hangar early), complacency (turnovers), and frustration (from the inadequate turnovers, lack of hangar space).**

Crew Coordination?.

Communication -Yes. Verbal and non-verbal communication failures dominated the shift turnovers. Pilots also had no notification of repairs.

Assertiveness -Yes. Supervisors, inspectors, and mechanics all failed to demand appropriate turnovers. Second Shift mechanics did not demand work cards from their supervisor when they began the boot repairs to assist the Third Shift. And, the final installation was completed outside in the dark…no one demanded additional lighting or repositioning of the aircraft back in the hangar.

Adaptability/Flexibility -Yes. A/F failures occurred when (1) the second shift started the boot replacement without work cards to help the third shift, (2) the inspectors became mechanics by assisting with the maintenance tasks (removing screws/installing deice lines), and (3) when the aircraft was moved outside to accommodate more maintenance within the hangar.



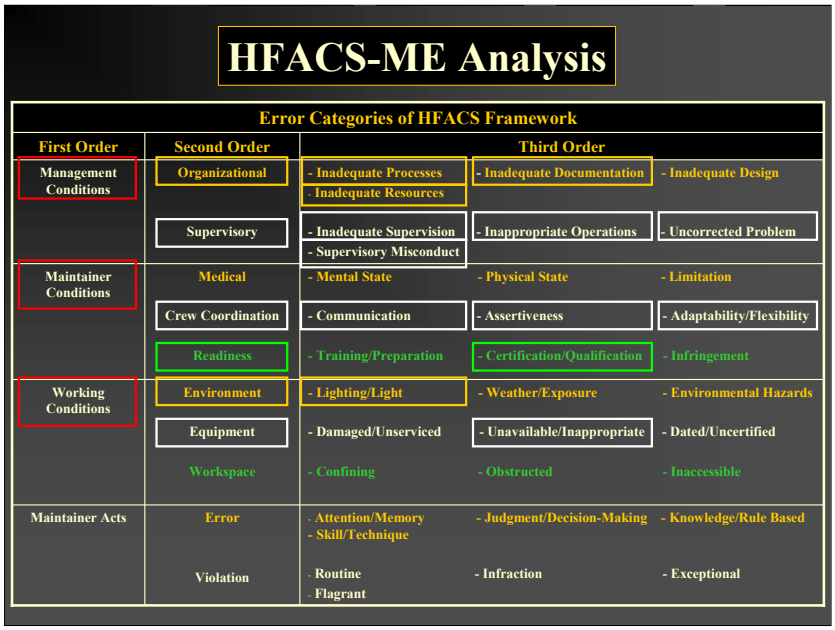
Readiness?

Training/Preparation No deficiencies were noted in the report. In fact, procedures were generally known.

Certification/Qualification -**Yes**, but only in respect to the continued qualification of the Second Shift inspector who was warned twice in the previous month and failed to show much improvement when he removed the screws without an adequate turnover.

Infringement (or violation) None noted. This category includes issues such as intoxication, but all maintenance personnel tested negative on drug and alcohol abuse. (Again, HFACS directs our attention to the possibility of those factors for further investigation.)

Let's move on to Working Conditions (quickly go to next slide).



Working Conditions factors were evident in the Case Study, but were not even mentioned in the NTSB's conclusions, probable cause, contributing causes, or recommendations! HFACS-ME, in this case, offers an organization much greater insight to these problems.

Environment?

Lighting -Yes. Lighting was poor outside the hangar where the final maintenance was conducted. The final inspector, who gained access to the T-tail to reinstall the right side deice lines, did not even notice the missing screws on the left side due to the darkness.

Weather/Exposure was not a factor.

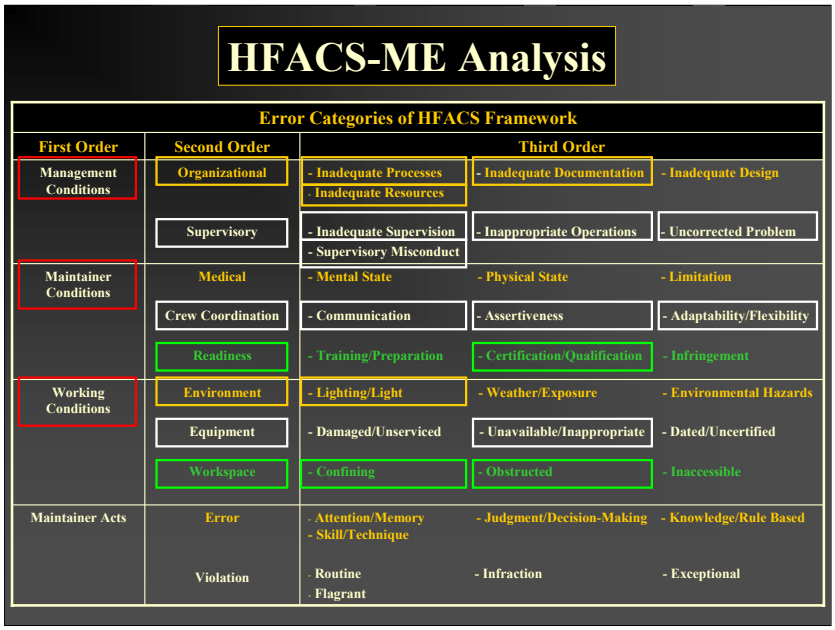
Environmental Hazards No fall/slip or other hazards were reported in this case study for an accident cause factor. However, the lack of lighting outside the hangar might increase one's chances of injury through falls, so this demonstrates the benefit of HFACs in not only identifying accident factors, but also drawing attention to other hazards.

Equipment?

Damaged/Unserviced None noted.

Unavailable/Inappropriate -Yes. Lights were not available outside the hangar. Hydraulic lifts were available to access the T-tail, but both inspectors climbed on top of the stabilizers. More information is needed to find out if the available lifts were inadequate, damaged that they could not be raised higher, or the inspectors simply chose to climb onto the T-tail. Again, HFACS gives us another issue to consider. This is particularly true in the hazard (non-cause factor) of the unavailability of the elevator balancing equipment…so HFACS can be used for hazard reports, as well.

Dated/Uncertified None noted.



Workspace?

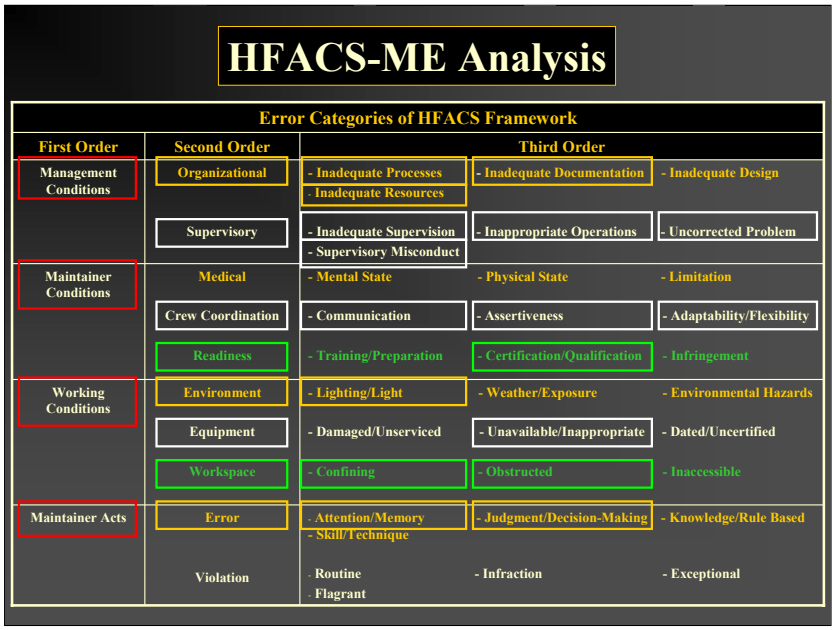
Confining -**Yes**. The aircraft had to be moved outside because the hangar was too confining to bring in the other aircraft. The maintenance on the aircraft itself, however, had no problems of being confining near the T-tail.

Obstructed -**Yes**. The missing screws could not be seen from the hangar floor due to the tails height and their location on the top of tail (obstructed view).

Inaccessible No. Although the inspectors climbed onto the tail, it was still accessible. If they couldn't reach or see something at all, then it would be a factor.

And finally, let us take a closer look at Maintainer Acts…

(quickly go to next slide)



Were there any factors within the Maintainer Acts categories?

Errors?

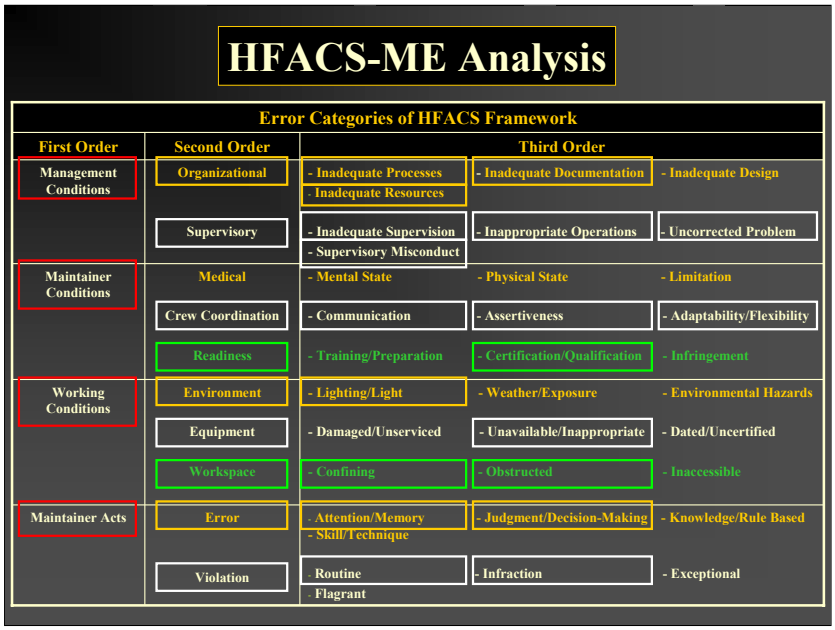
Attention/Memory: **Attention** - **Yes**. The final inspector did not notice the missing screws (aggravated by darkness). The mechanics who replaced the screws did not think to check all work areas for missing screws when, even though they used both old and new screws, they "only" had a dozen old screws left. Memory - No, but possible. Memory failures on turnovers could have occurred, but the evidence currently points to decisions among the supervisors to avoid turnovers and appropriate procedures.

(**Facilitator**: This a perfect time to note how the factors tie together through the HFACS-ME Framework…his attention was degraded by darkness, the working conditions had inadequate lighting, and the supervisors failed in several ways to accomplish the tasks with the organizational inadequate resources of hangar space and poor outside lighting.)

Judgment/Decision-Making -**Yes**. The second shift supervisory exercised poor judgment by starting the boot replacement without work cards. The decision to move the aircraft to an unlighted area for final repairs and inspection. Also, assumptions made during turnovers without verification, to name a few. (Time permitting, allow the students to discuss others.) For a non-cause factor "hazard": the decision to use makeshift tools when conducting the elevator balance.

Knowledge/Rule Based No. In general, procedures were known, but often ignored or "modified" (i.e., Violations).

Skill Based No. There is no evidence of skill based errors on this case (i.e., no one damaged anything by being overly rough or untrained). However, the Second Shift inspector may have made a skill based error (as well as others) last month when he "missed a crack in an engine exhaust stack". Because it was not causal to this mishap, and he had no other skill based errors on this accident, it would be classified separately as a hazard vice a cause factor. As previously stated, the organization can use the HFACS classifications in correcting hazards, as well as, accident cause factors.



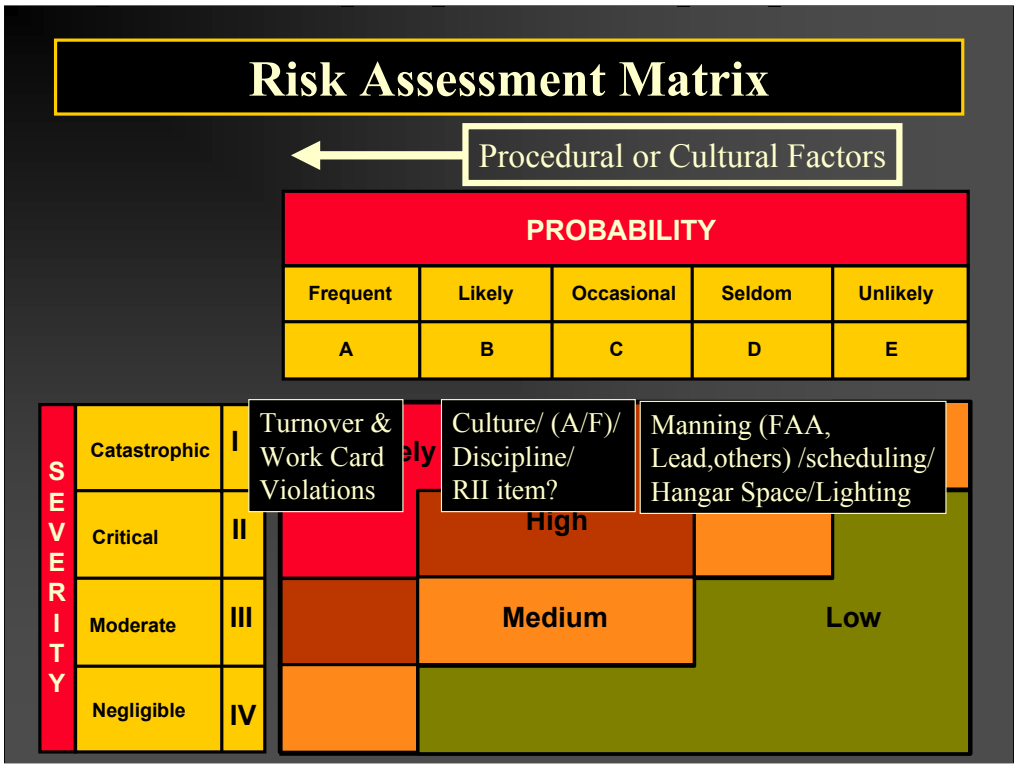
Violations?

Routine -**Yes**. The lax turnover procedures and inadequate documentation were not corrected. The organization had appropriate regulations, but they were routinely violated, possibly due to complacency, lack of discipline, and an overall inadequate safety culture (further investigation necessary). Also, inspectors conducted maintenance.

Infraction -**Yes**. Two events describe non-routine rule bending to save time. The Second Shift Supervisor started the repairs, without cards, to assist the Third Shift (normally they used work cards). The aircraft final repairs were conducted outside to expedite repairs on another aircraft in the hangar (they initially planned to do all of the work in the hangar).

Exceptional No, not as the case study is written. Although there were numerous violations of procedures, the intent and severity point towards Routine Violations and Infractions. There does not appear to be a conscious attempt to falsify inspections or maintenance actions. However, because HFACS-ME does consider intentions, it is therefore a very useful tool to remind investigators to seek further clarification on these issues during interviews.

Flagrant No. Despite the severity and amount of routine procedural violations and infractions, they were not blatant acts which defied authority and all consequences. (Flagrant violations would be appropriate in cases where one purposely risks equipment or ignores risk of injury to self and others.)



(**Facilitator:** Due to chart size and time limitations, only general factor areas are discussed. Time permitting, the same process can be used on ALL identified factors.)

Let us now apply our findings to the Risk Assessment Matrix…

Severity Hazards can exist at all levels, but in this accident, a catastrophic outcome has already occurred, therefore, all of the "accident causal factors" are of a catastrophic level of damage. The only difference in the individual factors is the probability that each will lead to a similar (or worse) accident.

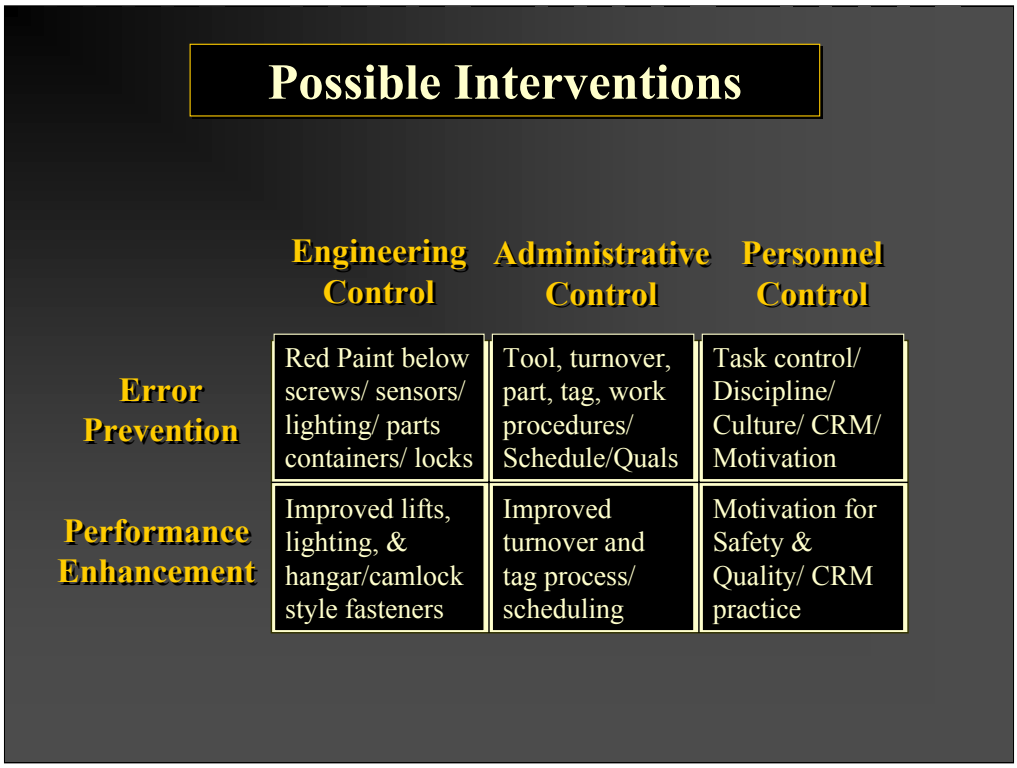
Probability Although all of the cause factors combined to form this accident, some of the factors are more likely than others to occur individually on future accidents.

-**Turnover/Work Card Violations** Failure to conduct proper turnovers/procedures, even if only done one time, will very frequently lead to errors. And when it is part of the culture, it has an even higher probability of occurrence (greater risk). These factors have a higher risk than the next two "blocks of risks" because the others at least retain the potential to still have work/procedures/etc. done correctly (i.e., a very likely error versus a possible error).

-Culture/Adaptability-Flexibility/Discipline? The cultural problems of poor procedural compliance and the tendency towards haphazard adaptation to changing requirements will likely result in errors. The failure to discipline the behavior of the supervisors even further perpetuates the poor working culture. **RII?:** The confusion over the RII designation may or may not have led to a more thorough examination under this working culture. It is certainly more risky than a "lighting factor", but it is less of a risk than purposely not using work cards and/or turnover Violations.

-Manning, Scheduling, Hangar Space, Lighting Combined with the other factors, these problems were causal to this accident. Individually, however, they are less likely to cause future catastrophic accidents than the factors in the previous "risk blocks". For example, if any or even all of these factors were evident in a workplace with a high quality/procedure-oriented culture, they would be compensated for differently….and the work would be better inspected, with work cards completed and turnovers done…in other words, there would be no missing screws in the first place.

Also note that "Procedural or Cultural Factors" imply that many individuals will do the same thing…increasing the probability of occurrence…a greater risk.



Facilitator: "Click" for each slide build to appear as you discuss the interventions possible within each "box".

And now we must develop our interventions based upon RAC severity (assume unlimited resources to implement your decisions for this exercise, however).

Error Prevention

Engineering Mechanical innovations to notice missing screws (red paint below screws, mech./elect.sensors?, better lighting); Devices to isolate removed fasteners and identify work in progress (portable parts containers); or Methods to prevent removal/loss of fasteners with improved visibility of work in progress (locks, camlocks, special tools that would have to be checked out, etc.)

Administrative All work procedures must be trained and problem areas revised. Scheduling should be changed to allow sufficient time to perform tasks safely and effectively. Qualifications should be reviewed and monitored.

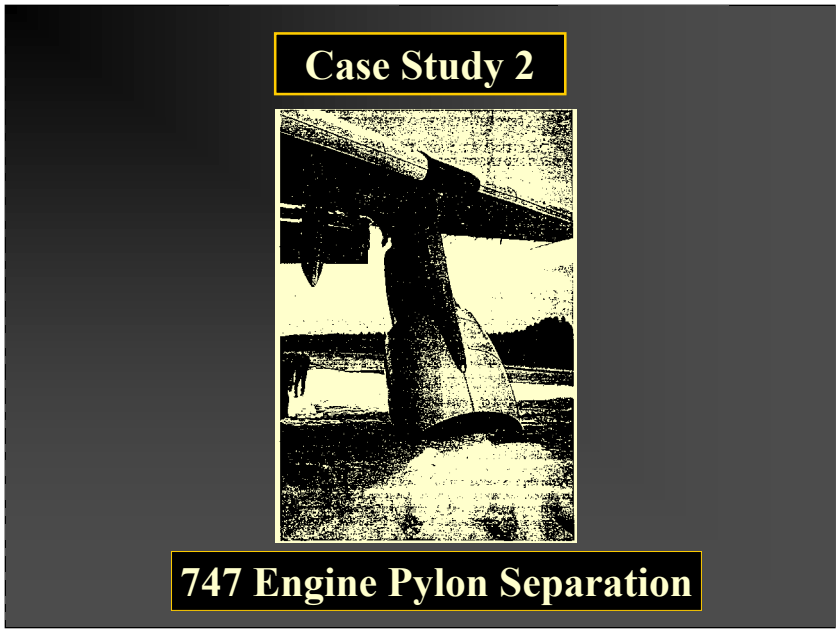
Personnel Individual discipline and task control will promote "ownership" of tasks and heighten awareness to follow on tasks. Ensure the workplace culture and daily use of CRM encourages procedure compliance and instills motivation.

Performance Enhancement

Engineering Design changes or improvements to lifts, lighting, hangar space, fasteners, etc. to facilitate fast and fail-safe task completion (to discourage "alternate" methods to work faster and/or limit damage while increasing output).

Administrative Turnover/Tags/Scheduling can apply to both Error and Performance changes. It increases performance by emphasizing quality over quantity to reduce accidents, rework, time delays, confusion, etc.

Personnel Personnel need motivation for improvement (e.g. safety/QA awards, recognition, promotion?). Each individual supervisor, inspector, or other worker must be motivated to perform their individual duties well. Time management and crew coordination/crew resource management will also increase performance when used, not just trained.



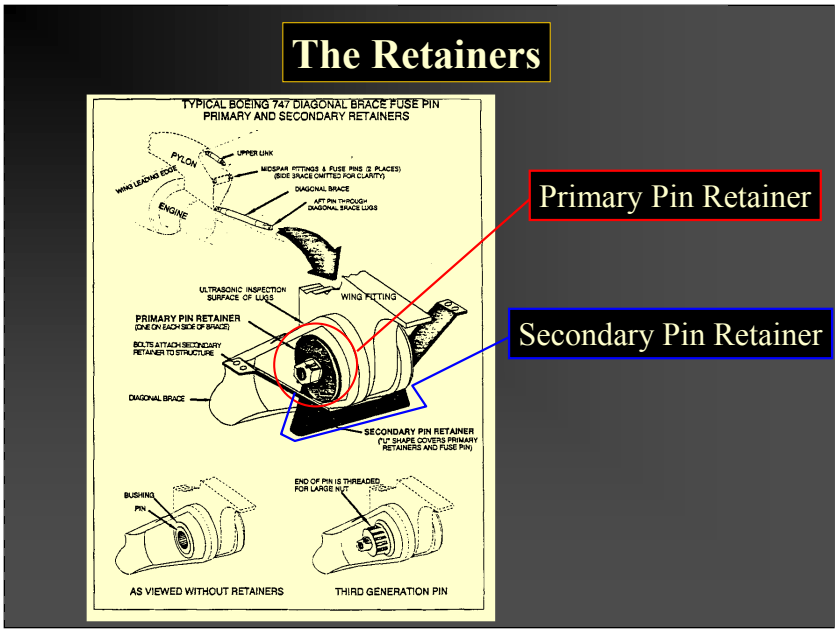
<u>Case Study #2</u>: 747 Engine Pylon Separation

The 747 landed safely at its first enroute stopover airfield, only to have the No.1 engine drop from its wing as the aircraft was completing its landing rollout! Imagine the consequences if the engine had fallen off in flight. The problem (the engine falling off) would be the same in both scenarios, but the results could be astronomically different. That is why we must study the non-fatal accidents, as well as incidents, if we are to make any significant improvements in lowering our accident rate.

Please read this case study carefully to avoid unnecessary confusion. It contains <u>detailed</u> discussion of work on two engine pylons and the actions of several mechanics, inspectors, and supervisors.

<u>Please read the Case Study at this time. (Go to next slide to show retainer diagram while students read)</u>

<u>Accident Photo</u>: retrieved from the NTSB Maintenance Accident Report Infobase, FAA/Galaxy Scientific, available at http://hfskyway.faa.gov., or on the Human Factors in Aviation Maintenance and Inspection CD, 1999.



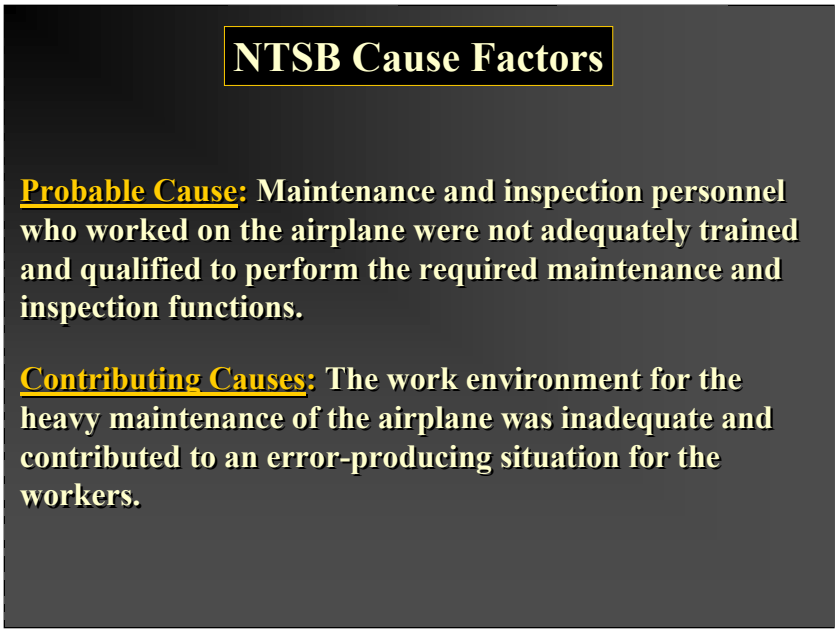
As the students begin reading, draw attention to this slide to show them the shape and arrangement of the primary and secondary fuse pin retainers on the aft pylon diagonal brace.

Clarify and summarize the case study with the following information:

- The secondary "C" shaped retainer was removed for the NDT inspection, but not reinstalled.
- The primary "washer/nut" retainer was not supposed to be removed and it also was not reinstalled. The NTSB never identified who removed the primary retainer, or why/when.
- The inspectors failed to discover the missing retainers on the No.1 engine pylon, and did not recheck it, even after finding and reinstalling missing retainers on the No.4 engine pylon.
- The accident occurred on the runway when the aft fuse pin (with neither the primary or secondary retainer) migrated from its location, causing the forward upper link pin to fail under the increased load.

Facilitator: Allow students to conduct their own analysis and discuss their findings prior to presenting the remaining slides (time permitting). Highlight the students' findings, questions, and discussion items during the remainder of the presentation to reinforce their grasp of the HFACS-ME framework and instill confidence in their ability to use HFACS-ME in the future.

(go to next slide)



Facilitator: The NTSB Conclusions, Probable and Contributing Causes are in the student's Case Study handouts. Students are encouraged to refer to the full text in their handout as you describe these key points.

The NTSB Probable Cause and Contributing Causes are only 2 statements derived from 12 conclusions. What do you notice? (Give the students a chance to answer!)

(1) The Causes involve only (a) training/qualification (probable), and (b) the work environment was inadequate/error-producing (contributing).

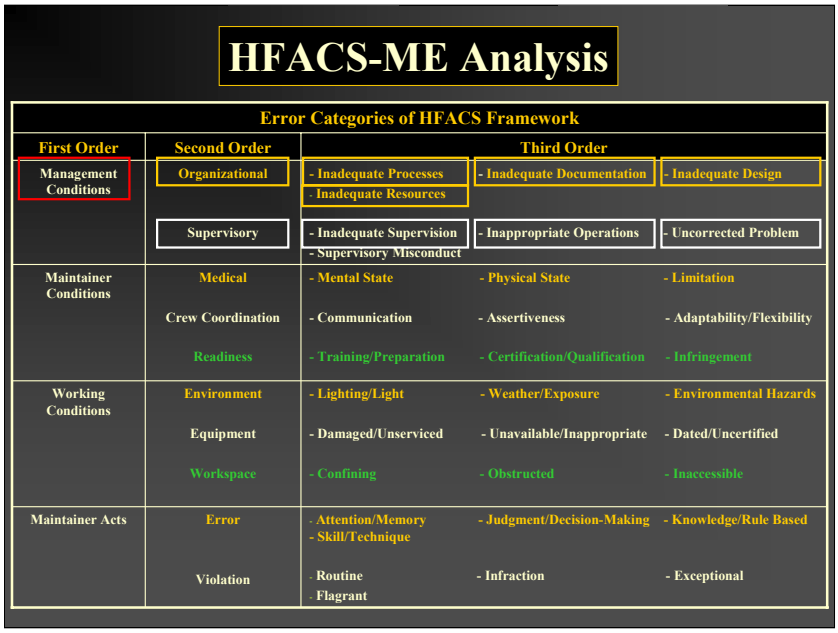
(2) The NTSB "Recommendations" ADDS one item from the Conclusions (that is not listed in the Contributing Causes), and another that is only in the NTSB's analysis section:

- CITEXT card review (Supervisory Documentation factor)
- Painting the fuse pins red so that missing retainers would be obvious (Supervisory/Design issue)

(3) No mention is made of supervisory/culture/discipline issues, even when the primary retainer is removed mid-maintenance without being noticed, without being scheduled, and especially without admittance by any member of the maintenance organization. This lack of information would even lead some to ponder the possibility of sabotage (a Flagrant Violation). There is no evidence for or against that theory in this report, it is just an unknown.

The HFACS-ME Framework would have reminded us to investigate those other areas. So let us now return to our HFACS-ME Framework handout and see how it could benefit our organization if this were our accident.

(go to next slide)



Facilitator: For brevity, only the "accepted" factors are discussed in the remaining speaker's notes.

<u>Management Conditions</u>:

<u>Organizational</u>?

Inadequate Design: NTSB suggestion of painted fuse pins to reveal missing retainers. Possible scaffolding design issues as well.

Inadequate Documentation: CITEXT Cards did not match the GEMM (which was adequate). Confusing Fuse Pin Retainer requirements. Inadequate red tag requirements. No turnover checklists.

Inadequate Resources: Lack of Storage, Poor Scaffolding, Inadequate Lighting. Director of Training position was vacant and staffed by a temporary director. Insufficient personnel for weekend shifts. FAA did not have enough inspectors.

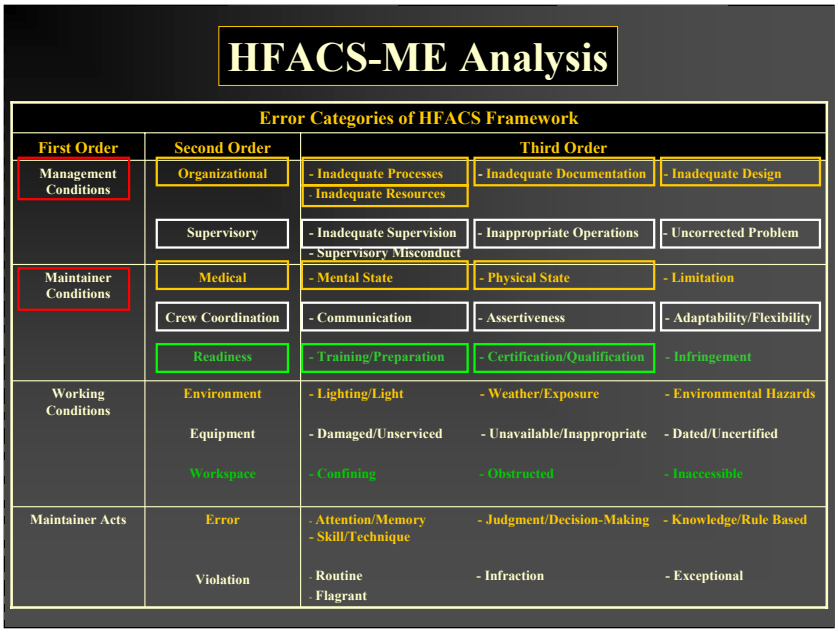
Inadequate Processes: Required the use of CITEXT cards despite known discrepancies. Did not adequately incorporate CITEXT system use and training and did not use inspectors in the CITEXT review process. Continued operations with known manning/training/procedural inadequacies. Over-reliance on OJT. Airline did not build a safety culture, which allowed routine maintenance shortcuts. FAA did not adequately monitor maintenance, inspections, production planning or the hangar's human factor discrepancies (lighting/scaffolds).

<u>Supervisory</u>?

Inadequate Supervision: Could not identify who/when/why on primary retainer removal**.** CITEXT card failures not adequately addressed. Failure to ensure adequate final inspection. Insufficient tracking of red tag use. Ineffective planning and monitoring of compartmentalized tasks.

Inappropriate Operations <u>Continued use</u> of hangar 6 lights/scaffolds with known safety and effectiveness hazards. Over-compartmentalization of maintenance tasks. Poor scheduling, combining of maintenance crews during weekend shifts. Inspectors overworked.

Uncorrected Problem: CITEXT Card use and training. Failure to utilize Red Tags on a routine basis. Inadequate lighting, scaffolds, parts storage and housekeeping. Trained personnel shortages. Ineffective scheduling.



Maintainer Conditions?

Medical?

Mental State The "OK to Close" inspector felt pressured to get the job done. Complacency/frustration with CITEXT work cards. Anxiety/confusion of weekend crews who were unfamiliar with tasks and crew assignments.

Physical State The "OK to Close" inspector was fatigued from working all night without break.

Crew Coordination?

Communication Director of Maintenance's written complaints on procedural errors were ineffective in changing maintenance actions. Compartmentalized tasks inhibited communication of any kind. Insufficient use of verbal, visual (tag), or written communication (documentation of work cards).

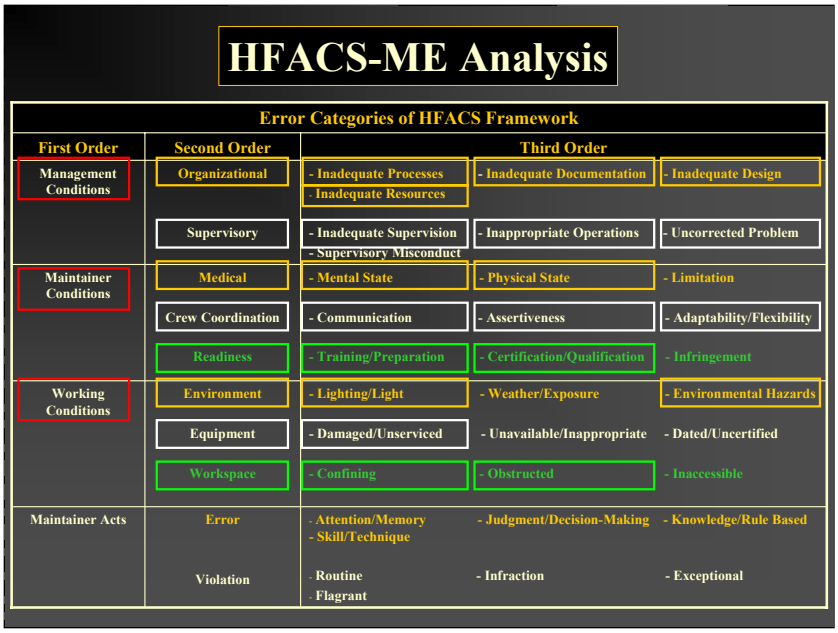
Assertiveness Director of Maintenance did not effectively stop procedural violations. Person who removed the primary retainer never notified others before or after the accident. No one demanded re-inspection of the No.1 pylon after retainers were found not installed in the No. 4 pylon.

Adaptability/Flexibility Multiple tasking and compartmentalization failures. Changing crew assignments and shift schedules promoted confusion.

Readiness?

Training/Preparation OJT failed to adequately standardize red tag and other non-standard procedures.

Certification/Qualification There were no certification issues, but the NTSB cited qualification problems with maintenance and inspections.



Working Conditions?

Environment?

Lighting/Light Lights were over sprayed with paint in hangar 6.

Environmental Hazards Fall hazard from "wood bridges" on scaffolding, especially while carrying additional lighting due to poor permanent lighting .

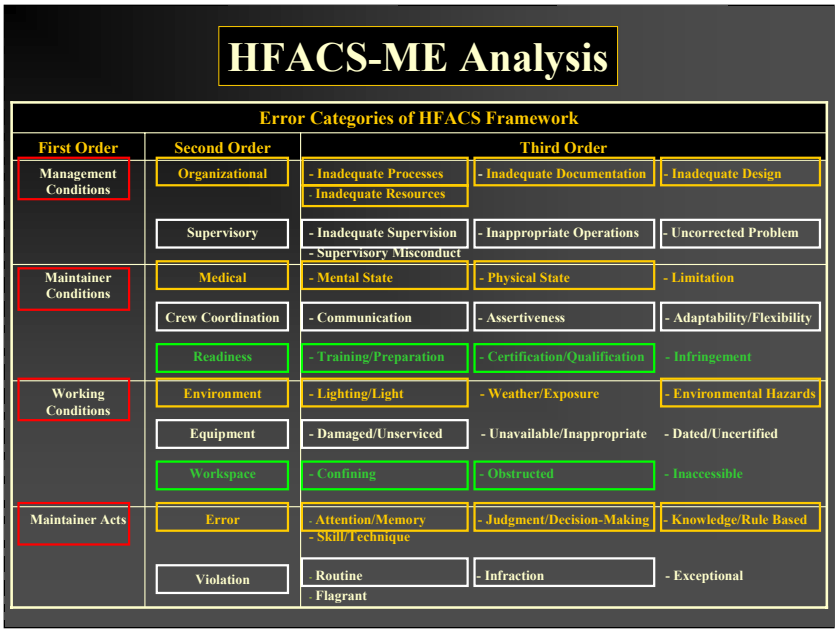
Equipment?

Damaged/Unserviced Scaffolds and lights.

Workspace?

Confining Inspectors had difficulty accessing the work areas near the pins/retainers from the scaffolding.

Obstructed Missing retainers could not be easily noticed due to accessibility/visibility problems when using scaffolding with poor lighting.



Maintainer Acts?

Error?

Attention/Memory No one noticed the removal of the primary retainer. The mechanics and inspectors did not notice the missing retainers prior to and during the "close up inspection". The bag of retainers was not noticed until after the accident.

Judgment/Decision-Making Red tags were not used in questionable cases (during all work here). No one chose to reinspect the No. 1 pylon after finding and reinstalling the bag of retainers for the No. 4 pylon. The inspectors chose to conduct less stringent inspections (this is not a violation, because they were still within their guidelines).

Knowledge/Rule Based The NDT inspector, and others, were confused on the requirements for secondary retainers. Red tag procedures were not standardized.

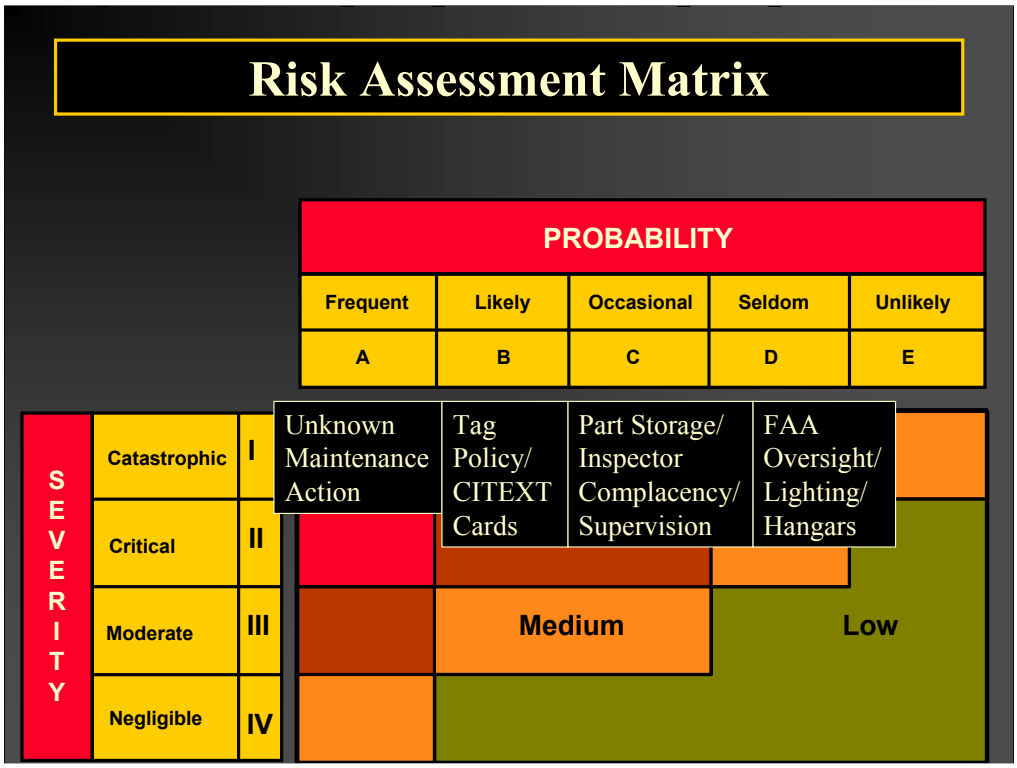
Violations?

Routine Storing/stacking parts together in areas that could damage the equipment and inhibit parts accountability.

Infraction Not documenting/red tagging maintenance when specifically required just to save time and effort. Inspection short cuts.

Exceptional/Flagrant??? Violations of this nature are not discussed in this NTSB report, but since there is absolutely no knowledge, admittance, or documentation of the primary retainer removal, there is a small possibility of a deliberate act. This should be thoroughly investigated and clarified in the report to eliminate future questions. HFACS fortunately reminds us of that remote possibility.

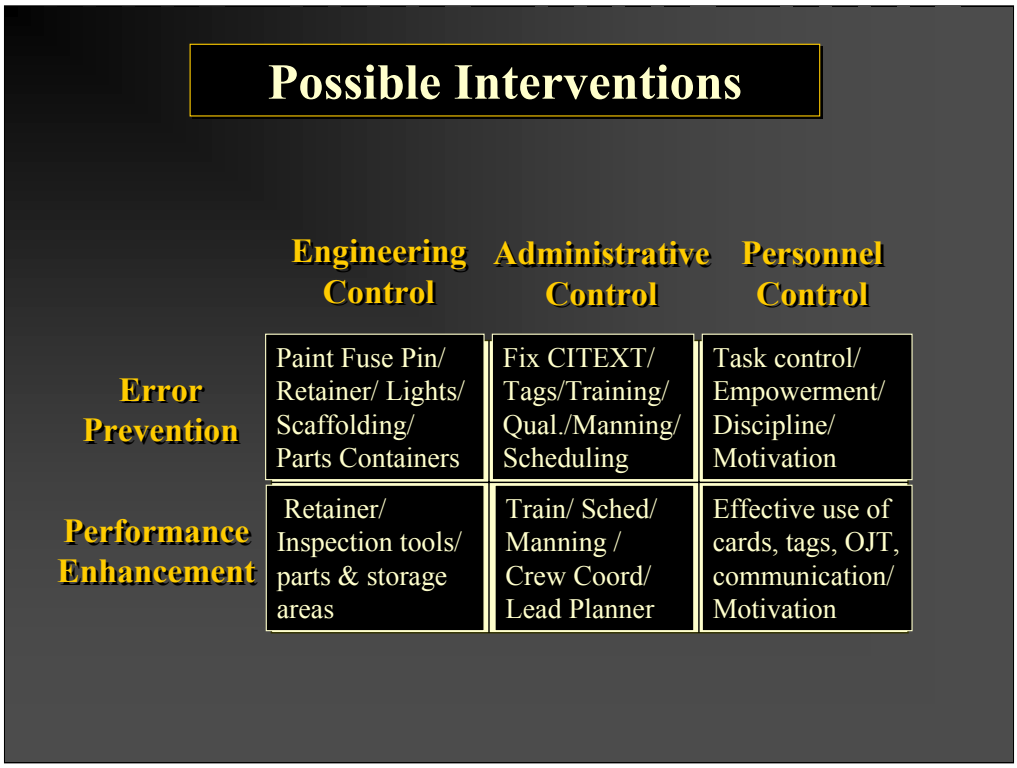
Ref: 03/01/94 Northwest Airlines Narita, Japan accident. Retrieved from the NTSB Maintenance Accident Report Infobase, FAA/Galaxy Scientific, available at http://hfskyway.faa.gov., or on the Human Factors in Aviation Maintenance and Inspection CD, 1999



Now we must apply our findings within the context of the Risk Assessment Matrix to determine which factors have the greatest potential for future accidents. Again, hopefully we will address ALL factors quickly and completely, however, if that is not possible, then the highest potential risks must be addressed first.

Severity As stated previously, all hazards (prior to an accident) can be estimated to have a certain expected level of severity. In this case, these factors definitely led to critical engine damage. However, it was only by luck that the engine didn't fall off in flight, which would almost have guaranteed a catastrophic result of an aircraft crash, and/or additional damage/deaths/injuries on the ground. Therefore, it is safe to say that these hazards had the potential to all be factors in a "catastrophic" level of accident.

Probability Without a doubt, an unknown and unscheduled maintenance action has the highest potential for disaster; Tagging and CITEXT card errors are also error producing (the CITEXT cards would be an even greater risk if the workplace culture actually relied upon them, but since they didn't trust them, they relied more upon the manual, etc. which slightly reduced the error potential); parts storage/complacency/poor supervision were all "close thirds" but would still only be a problem if the task was performed incorrectly; and the FAA/Lighting/Hangar factors are less likely to occur or make a difference because they are not of continuous use or concern on ALL maintenance.



Possible Interventions

Error Prevention

Engineering The NTSB recommended painting the fuse pins red for easy identification; the Pin Retainers could be redesigned to preclude removal for inspections/ Lights and Scaffolding could be improved to reduce inspector concern for falls and improve detection of errors; Parts Containers need to be built which can be effectively used in the work areas.

Administrative Correct the CITEXT cards; Ensure that tags, training, qualified personnel, and adequate manning are available and used effectively; Develop a tight and monitored schedule for maintenance and inspections to ensure quality and prevent any unknown maintenance actions.

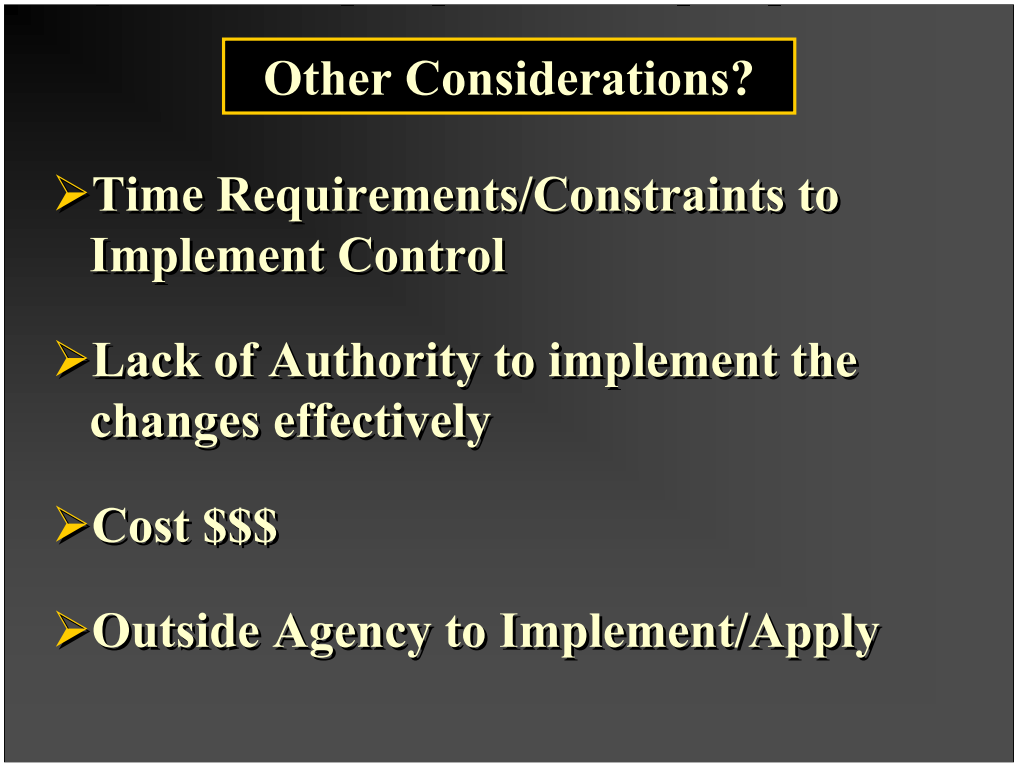
Personnel Individual task control and empowerment, as well as a little discipline and motivation, would improve maintainer "ownership and responsibility" for tasks. This would help to reduce the general practice of not knowing, or caring, about follow-on inspections/turnovers/etc.

Performance Enhancement

Engineering Redesign the retainer and inspection tools (or access?) to make the whole inspection process go faster (hopefully without retainer removal!); Redesigned parts and storage areas would not only eliminate errors of missing parts (or using damaged ones) it would also increase speed and efficiency of repairs and inspections.

Administrative Adequately training personnel while ensuring that manning and scheduling were sufficient would prevent errors and lead to faster/safer maintenance; Crew coordination on the part of all personnel would prevent confusion of tasks and prevent doubled efforts; a Lead Planner to coordinate all activities per airframe would be ideal.

Personnel Effective use of cards, tags, and communication would be enhanced by the individual efforts of "instructors" during OJT. Motivation can be instilled and cultivated in the new personnel while being further practiced by the senior maintainers.



Other Considerations?

Are there other considerations which may affect our intervention strategies?

We just completed our list of interventions based upon unlimited resources to eliminate ALL hazards.

Let us now review our list of interventions considering these four new constraints and discuss whether it changes our strategies:

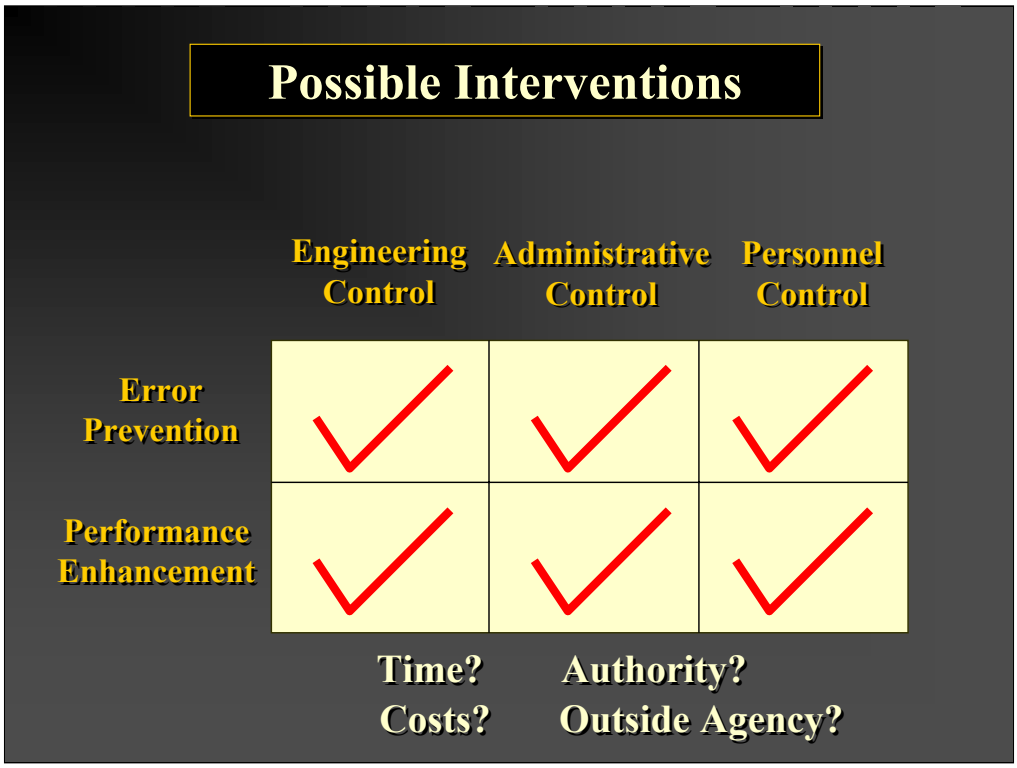
Time Requirements/Constraints to Implement Control

Lack of Authority to implement the changes effectively

Cost $$$

Outside Agency to Implement/Apply

(go to next slide)



Facilitator: Have students discuss changes in possible interventions, per category, based upon one or more of the following considerations. Discussion of strategies within the "confines" of an organization is very realistic for managers and supervisors. Allow sufficient time for discussion so that all students appreciate the difficulties faced by supervisors in responding to accident recommendations.

Time Requirements/Constraints to Implement Control

Lack of Authority to implement the changes effectively

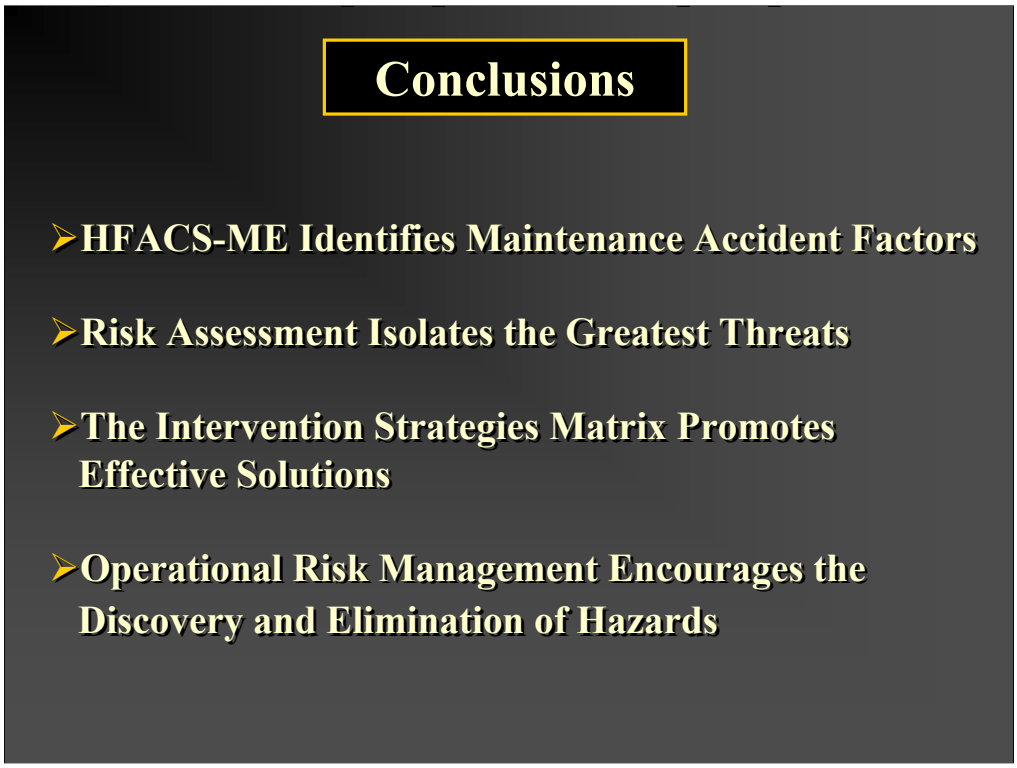
Cost $$$

Outside Agency to Implement/Apply

Example: More than likely, several engineering ideas (other than simple "flags", signs, etc.) are often unrealistic interventions for incidents considering the cost and time to implement them. However, if a particular engineering solution could be made to eliminate a frequent & catastrophic factor in multiple hull loss aircraft accidents, almost any "cost" would be approved.

Bottom Line: Interventions are "acceptable" if they fall within an organization's implementation constraints. However, "unacceptable" interventions should not be abandoned and forgotten! Safety personnel should modify or create new interventions to continue the effort to eliminate cause factors of accidents.

In other words, don't give up because of a few constraints…be creative and flexible!



Conclusions:

HFACS-ME Identifies Maintenance Accident Factors

Risk Assessment Isolates the Greatest Threats

The Intervention Strategies Matrix Promotes Effective Solutions

Operational Risk Management Encourages the Discovery and Elimination of Hazards

Questions?

This concludes the HFACS-ME Training Program and Workshop.